PLM opportunities and weaknesses to support collaborative engineering.

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PLM OPPORTUNITIES AND WEAKNESSES TO SUPPORT COLLABORATIVE ENGINEERING

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ABSTRACT

The aim of this paper is to discuss the opportunities and the weaknesses of Product Lifecycle Management (PLM) technology to support collaborative design process. Whereas Product Lifecycle Management tools are deployed in many firms, only few studies highlight their impact on design processes. Engineering literature focus on the technology itself (and not on processes) and management literature does not deeply investigate this matter.
The study is based on a 3 years analysis of a PLM system project in a large French company, int the sector of small domestic appliances. The research design is based on a single case study which corresponds to a business unit dedicated to Linen Care product family. In the first part, we highlight how PLM offers functionalities that facilitate the stakeholder coordination during the design process (Stark 2004). This IT tool offers a structured framework for collaborative Engineering and fosters the definition and standardisation of workflows and intermediary objects that are produced and used during the design process. In the second part of the paper, we discuss the weaknesses of that technology to support the day to day collaboration and the creation of new objects. We show that PLM enables to share elaborated design information whenever it fails to support data elaboration process. Social aspects of collaboration like confidence, engagement are not taken into account in the PLM systems. Finally, we highlight that the implicit model of coordination in PLM exclude cooperation. This case study allows us to discuss the necessity fort different collaborative workspaces which refer to different design collaboration needs.

INTRODUCTION

NPD process becomes more and more open, integrating sooner new stakeholders from inside and outside of organisations. Integration of suppliers in design and co-development becomes a major issue in NPD. To reach this objective, it is necessary to define clearly rules and milestones to coordinates concurrent design processes that constitute the projects (Malhotra, Gosain et al. 2005). This minimal structuring is facilitated by the stage gate approach (Cooper and Kleinschmidt 1990; Howe, Mathieu et al. 2000) that allows to structure a common framework for collaborative working. This new context increases complexity of information flow and workflows. Thus it is

necessary to define minimal rules for coordination and also to facilitate direct collaboration between actors for daily design work.
To facilitate collaborative engineering, a fast growing technology is spreading in organizations. This PLM (Product Lifecycle Management) technology appeared in the late 90s coming from Product Data Management (PDM), a technology dedicated to product data management inside companies. Since late 90s, many industrial companies have chosen to implement PLM technologies in order to improve new product development productivity (Gartner Group, 2007). Editors of this fast growing technology communicate on potential performance due to PLM such as leadtime reduction, quality improvement.
One of the objectives for collaborative engineering especially in a context where co development becomes a standard is to take into account external actors in the design process and so ensure sufficient structuring of the design process to facilitate external integration. A key issue is also the knowledge sharing in this large network that designs a New Product. Integration of many stakeholders from distinct disciplines (Hatchuel and weil 1999) and from different departments is a critical factor for NPD success.
Our question is what is the real value added of this technology to support collaborative engineering? Does PLM really support this collaborative engineering? Is this technology supports interactions between actors, knowledge sharing or mainly supports product data management?
This research had been carried out in participating of a three year project of deployment of a PLM within a French industrial firm.
In the first section we will describe some requirements for collaborative Engineering information management based on literature and previous works on design studies. Thus we will present the key functionalities of PLM technologies. The third section precises the context of our case studies and methodology used for data gathering and analysis. The last section proposes key results on PLM opportunities and weaknesses based on field observation.

INFORMATION SHARING IN COLLABORATIVE ENGINEERING

Collaborative engineering can be defined as the progressive construction of a new product based on continual interactions between actors coming from different departments. These interactions are supported by a wide variety of artefacts and information. One of the main goals is to ensure integration between actors having different cultures, targets, knowledge and ensure that each actor participates to the same goal: the development of a new product. This integration is threefold: vertical in the supply chain, horizontal in the organisation (many departments involved) and geographic between specific location of large companies.

Collaborative engineering: the key role of intermediary object

Design work is related to the production and the use of information. But information produced by the stakeholders of the design is rather heterogeneous, such as digital models, drafts, tables of data, as plans or prototypes, etc. This communicative activity is supported by many artefacts during the design process. We assume that it is useful to take into account all those artefacts to understand the nature of collaborative Engineering. Thus we use the concept of Intermediary Objects (IO) (Vinck and Jeantet 1995) to describe objects or documents that appear or are used in the process, whatever be their form, origin or destination: schedules, minutes, functional graphs, calculation results, drafts, 2D plans or 3D models, prototypes, etc. Those IO can be seen not only as resulting from the design work but also as supporting and highlighting it (Blanco and Garro 1996). The term of Intermediary Object serves as a generic designation that is useful. It enables to raise a general question about how the design processes under study works? This is due to the features of the IO: modelling the future product and acting as communication vectors between the product designers. These two aspects are so much connected in the reality of the process that we cannot isolate one from the other without deforming their nature. As a vector of communication, objects structure the design network. Like models of the future product, they highlight its evolution. All the intermediary objects do not have the same characteristics in design. Those characteristics depend on the properties of the object itself and on the situation of action in which it is committed . Intermediary Objects can be characterised on two axes. Depending on the margin that is given to the user, we identify the *open or closed objects*. A closed object transmits a strong regulation, whereas an open object is a support for negotiation. Deliverables produced for project milestones for examples are *closed objects*. Drafts and preliminary information are *open objects* that are used, exchanged, to support negotiation and the solution emergence. The position of an object on this first axis (open to close) depends on the status of the information given by the actor and on the object itself. In a sequential model of the design process, closed objects support most of the information. As the engineering processes become more and more concurrent, the role of the open objects is increasing (Terwiesch and Loch. 2002).

The second axes for characterising IO is linked to the degree of interpretation they allow to their user. These objects are not just symbols, nor neutral instruments, vectors of univocal or determining information. On the contrary, there is always the possibility that they will be interpreted and used in different ways. They offer holds; they provide a framework for action and suggest interpretations. They act as mediators. Therefore the level of mediation provided by the object can be evaluated from a theoretical *commissioning object* which would transmit the whole intention of the provider, without transforming it, to a *mediating object* that offer a wild level of interpretation for different users. In that sense, we consider that IO provides a new point of departure, offering future perspectives while limiting the possibilities for action.

It is possible to distinguish mediating IO from commissioning IO. Commissioning IO corresponds to a prescription which leads to limit co-construction and to impose a solution. Mediating IO corresponds to an object which stimulates mutual adaptation between actors. Technical standards on a product can be considered as closed commissioning IO whereas paper drawings are generally used as a open mediating IO.

Thus all Intermediary Objects do not have the same characteristics in design activity. In order to understand the objects evolution within design projects, it is important to observe the designers practices. This observation shows that the uncertainty and stability of information evolves during design.. Collaborative Engineering and concurrent overlapped activities in design imply to share non mature information that was presented as preliminary information by Clark and Fujimoto (1991). Immature information are tentative, untested and possibly incorrect elements (Hanssen 1997). Several authors were interested in the maturity of the preliminary information management from different points of view (Helms 2000). Maturity Management is a key issue for project coordination, for communication facilitation and also for risk management.

Linking process management and information flows

This point has been well developed in the literature (Krishnan and Eppinger 1995; Terwiesch and Loch 1998). The overlapping of the activities imposed by concurrent Engineering organisations had modified the information flow in the design team. The role of preliminary information is increased. The scheduling of project has to include coordination strategies to avoid major reworks or starvation. The risk encountered by the project depends on the coordination strategies chosen. Terwiesch (2002) emphasises that the designers have to choose between different strategies of coordination. The decision of sharing an information depends on the knowledge of upstream activity the provider's one and on the knowledge of needs and constraints of downstream activity. In the large system design team, Eckert had shown that the actors poorly knew other team's schedules and needs about information. The authors highlight the lack of overview of the design process and the misunderstanding of context of the information that the designer used (Eversheim, Roggatz et al. 1997). This point of view emphasises the need to improve communication of the context of information.

All these approaches highlight the necessity to rely the information management to the project management point of view. They claim that an information-based project management is more efficient than an activity-based project management. Those works give a great contribution to the understanding of information management in design. However they have to be completed because they mainly focus on Information Systems and are based on the hypothesis that the design process is well known and predictable. Many observations of design had shown that the whole design process could not be predictable and planed. Problems and solutions emerge during the design process that had not been identified previously. So the exchange of information could not be entirely identified and analysed in term of coordination strategy. Moreover the exchange of information has to be understood, including social aspects of the co-operation. In the next section we would focus on practice of the information sharing in design activity.

Sharing workspaces for collaborative engineering

The workspaces in which designers discuss and built information are also evolving in a consistent way with maturity of information. We identified four workspaces (private, proximity, project and public) that corresponds to different type of regulations, level of trust and engagement of the information provider:.

First, the designer produces its proper ideas and solutions based on available information and on his own knowledge and competences. This information is arranged in draft object which are kept in the personal (private) workspace of the actor (for example designer's desktop as printed objects or his hard disk as numerical data). Drafts are not shared and they do not have to be.

Then the designer needs to confront his/her ideas with other actor's point of view. In this step, the collaboration is reduced to a *proximity* workspace, based on his personal network and loyal relationships. In the proximity workspace, the designer can expose himself to the critics and judgment of others. This workspace is build for a specific need and could evolve during the project, depending on the competencies of the actors. The actors of this ad-hoc workspace can be inside the official project team or outside. This is the place of informal confrontation and advice. The role of this space is the construction of a robust and convincing discourse to argue the solution. It is an informal validation of the solution. When the argumentation is coherent and when the information is considered as enabled to be used, it can be transmitted outside the personal network. Lecaille (2003) uses the term enabled trace to characterise the status of this information. It is non-officially validated but sufficiently convincing to be published.

Thus the designer spreads the information to the concerned user(s) in agreed workspaces (the common database or PDM system). Project workspace corresponds to the coordination level of project activities which are planed beforehand. That is the case for the electronic engineer who places the circuit diagram in the project shared space in order to enable to the mechanical engineering designer to retrieve it.

Finally, the information is formally validated by the hierarchy: project team manager, department manager, etc. Most of the resulting objects will be published as deliverables in the PDM systems which are the official workspace for the project. The evolution of the information from a draft to the enabled status is not linear. In any time of the design, information can evolve from one status to another and vice versa.

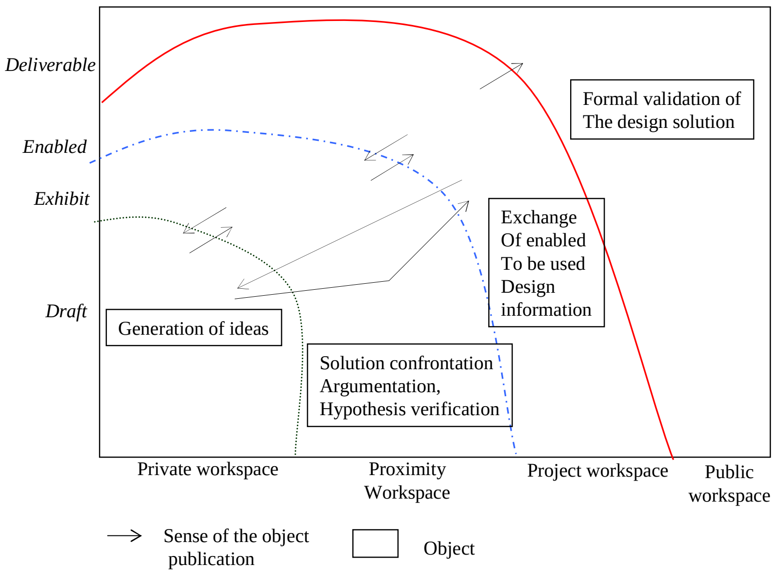

Figure 1: Design object status evolution through workspaces

Thus the observation of design activities shows that the information flow are complex in the design process. PLM systems tends to support this collaborative engineering by offering certain functionalities. The section below describes the functionalities implemented in the PLM technologies.

PLM TECHNOLOGY FUNCTIONALITIES

Historically, PLM comes from *Engineering Data Management* (EDM) tools which were originally dedicated to engineering teams and then became *Product Data Management* (PDM) when they integrated datas from departments such as quality, standards, laboratory (Lund, Fife et al. 2005). PDM manage technical and project data such as commercial launching plan, technical specifications, plannings (Pol, Merlo et al. 2005). PDM tools manage product information through object storage and workflows. PDM became PLM solutions at the end of 90's when this application opened to other departments (marketing purchasing etc.., included project planning and monitoring and aimed at covering the whole product lifecycle. PLM solutions offered by editors come from 2 different environments: ERP (Enterprise Ressource Planning) environment and PDM environment. This IT tool aims at offering a structured framework for collaborative Engineering and fosters the definition and standardisation of workflows and intermediary objects that are produced and used during the design process (Batenburg, Helms et al. 2004). This technology implemented a stage gate philosophy to manage new product development process. There is a difference between the PLM concept, PLM technology which mainly covers the product lifecycle management but not the whole Supply Chain Management process. The connections between ERP technologies and PLM technologies are at least incomplete. Préciser (tableau avec perimeter fonctionnel

The main functionalities of this application are organized around 3 main topics: communication, storage and monitoring functionalities.
Communication functionalities relies on several elements, they are mainly concerning asynchronous communication:

- The 2D and 3D viewer Before PLM, it necessitated CAD softwares to access to 2D and 3D product models. So a limited number of project members could visualized product volumes and styling for example. The viewer enables to view CAD elements for all PLM users even those who are not CAD practitioners as purchasers for instance.
- Workflows facilities. They are a key component on the design process to structured information flow. Thus, automatic micro processes enable to manage validation and diffusion tasks between different actors.
- Automatic object generation in sharable format (pdf) facilitates exchanges.
- Some PLM environments also include Synchronous Communication facilities for distant meeting and application sharing.

Object and data storage is a key element from PLM technology.

- Data Organisation: PLM offers a pre defined project structure based on a template that becomes a Standard for all stakeholder of the design process.
- Unicity of data: With PLM, there is a unique database for projects and products creation accessible from all project members with access right.
- Tracking functionality. This point drastically improves reliability of NPD process. Object evolution is tracked through revision index and status.
- Classification of objects. Objects collected in PLM are stored depending on their types (marketing, quality…) which facilitates object reuse and search.
- Use case of components. The way to manage objects through links between objects enables where used. For each component, it is possible to analyse in which finish products component is used.

Project monitoring

- Project planning: is connected to deliverable and information management in a single work environment. The NPD is implemented in the PLM system
- Project monitoring: The coexistence of Project plan and Product data allow to follow there are performance indicators through specific dashboards.
- multicriteria search enables to easily find objects depending on selected criteria

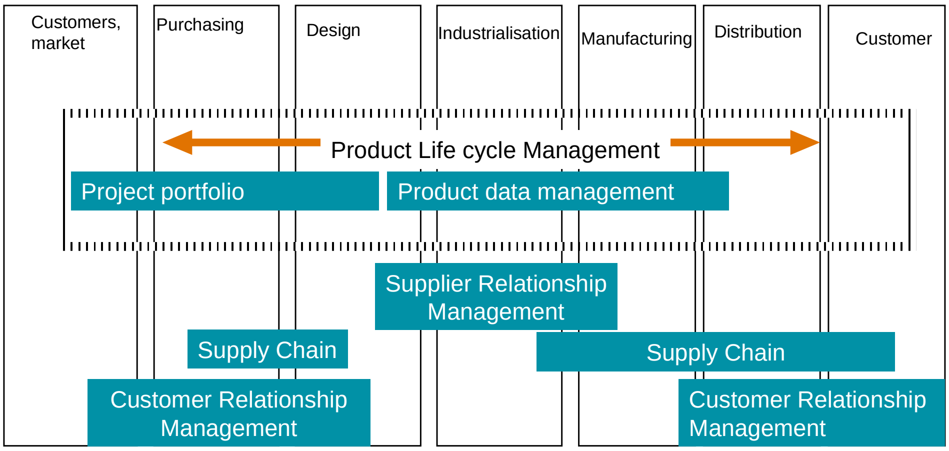

Figure 2: PLM location in Information System

From the concept and the promises of PLM editors, our question is what are contributions and limits of PLM technology in collaborative engineering? More precisely, we want to understand and analysis what is the real use of PLM technology in daily design process ?

RESEARCH CASE AND METHOD

We start with case study description and then we precise methodology, data collection and analysis.

Case study description

This Group is a French industrial actor for small domestic appliances with international brands. This company (€2,8bn turnover) has a strong tradition of external growth with multiple acquisitions. The organisation is based on business units (BU). There are 5 business units organized around product families: cookware, electrical cooking, food and beverage preparation, linen and personal care, home cleaning. In this research, we concentrate on Linen Care activity which was the pilot entity for PLM implementation. The overall context for this Group is a strong competition from Chinese, pressure from distributors and important changes in consumer behaviour from the beginning of 2000. This industrial group has decided to implement *TeamCenter Engineering* solution from Siemens in 2004. PLM project was launched in the objective to reduce project leadtime, reliability of finish product and productivity. In 2005, the Linen Care business unit was the PLM pilot started to use PLM technology. Linen Care business unit develops iron steams and generateurs vapeur. After 3 years of PLM use, we can consider that the appropriation phase is finished and it is so possible to analyse the real use and value added of this solution for collaborative engineering. Design teams is composed of 70 people. 30 people belong to engineering design from which 5 are project leaders. Nearly 30 people take care of industrialization of new products. Marketing team is composed of 10 people, 12 are dedicated to quality and labs test and 2 for standards. In 2007, 12 projects were managed by the Linen Care team including new products and product renewal.
Before PLM deployment, this design team faced several problems. Thus, intermediary objects were split in several IT tools depending on the department owner and so it was

difficult to have a consolidated view of projects. There were technical difficulties to interface different applications. Thus, CAD drawings were only accessible through CAD tools, there were no interfaces between technical database and manufacturing IT tool and no interface between technical database and ERP. This was problematic because of data multiple collection and errors due to several databases. Finally, specific developments or old IT solutions were hardly accessible from distant geographic sites. Most of validation processes were performed manually and there were problems to track object sharing.

Longitudinal Qualitative Methodology

Due to our pioneer analysis of contribution of PLM technology on collaborative engineering, we adopted a qualitative approach based on a single case study, observed during a period of 3 years. The design of this research is grounded on a longitudinal real time approach (Leonard-Barton, 1990; Eisenhardt and Graebner, 2007) in order to deeply understand the context, social and political interactions between actors and technology. In this case study, we analysed in details 6 projects in order to better understand knowledge integration in daily new product development process.

The case study corresponds to a business unit dedicated to Linen Care product family from a small domestic appliance company. This unit was the pilot entity for the PLM tool, TeamCenter Engineering from Siemens, implemented in 2004. This SBU is characterised by a design process which is based on more than 60 people, with complex product architecture and the increasing outsourcing of finish product key components to suppliers.

In this case study, our unit of analysis is the project. We deepen the analysis of 6 projects in details in order to identify PLM use, nature of objects collected in PLM application and the king of facilities which are really used by actors. The choice of projects is mainly based on the representativeness of diversity in projects with 3 types of projects: radical new products, new product architecture and product renewal (Wheelwright and Clark 1992). All 6 projects include components externalisation to suppliers.

The observation process has been organized in 3 main phases: diagnostic before PLM implementation, reorganization and implementation process and post implementation phase.

Data collection and analysis

Data collection relies on a combination of interviews, project documentation, observation and basic statistics from PLM solution. 56 interviews were conducted: 16 are totally transcripted, the others are summarized by interview notes. Interviews were conducted with various profiles such as marketing, styling, engineering, quality, standards. Actors interviewed occupy different positions in organization: top management with VP industry, middle managers with project leader and technicians from quality for example. Daily observation of the PLM project is collected through field notes. Every day, we collected some key ideas, description or sentences from participating observation in the PLM implementation project. We had no restriction on documentation access. That means that we could collect all mails, specifications, presentations and key exchanges on the project. We also used some statistics (from PLM application in order to better understand the operational use of this application.

DATA COLLECTION		Phase of longitudinal analysis		
LINEN CARE CASE STUDY		Before	During	After
Interviews	*Collective*	5	0	N/A
	Individual non recorded	20	20	N/A
	Individual recorded	N/A	N/A	16
Data collection	*Secondary data*	All documents concerning analysis phase: mails, specifications…	Documents such as implementation rules, procedures	Documents such as project communication, trainings…
Observation	*Field notes*	Daily field notes depending on observation of different departments	Field notes on choices and arbitration on implementation rules in PLM	Field notes during trainings, post implementation support
Artefacts	*Artefacts*	N/A	N/A	Basic statistics from PLM: number of users, number of objects per project…..

Figure 3: Data collection

Data analysis is based on a theoretical coding table created from theoretical constructs (X). Data coding is based on theoretical constructs of maturity workspaces. The interviews, documents and field notes have been coded in Nvivo7 tool.

OPPORTUNITIES AND WEAKNESSES OF PLM TECHNOLOGY

This research shows that PLM use can be quite different from PLM editors prescribed ideal use. The daily use of this IT solution shows that PLM facilitates project management but has a limited value for daily collaborative work especially during preliminary design phase.

PLM facilitates project monitoring and mature objects sharing

PLM supports structuring of new product development process

PLM relies on content based principle. This technology is primarily done for project and product objects storage. Thanks to a unique database for all actors involved in the development process, all codified objects are stored in a predefined project structure which enables to facilitate objects sharing and reuse. In our case study, the project structure is organized around department folders and subfolders. Project structure is considered as a template in PLM and so all projects have exactly the same structure. Under folders and subfolders, objects storage is predefined. The location of each key object is defined in order to facilitate exchanges and sharing between concerned actors. Thus, marketing specification is available in the project structure under marketing folder, under specification subfolder. This facilitates daily reciprocical prescription (Hatchuel, 1994) between actors. Thus, each actor knows where last shared version of document is available in PLM structure. In order to follow modifications on marketing specifications, all modifications are tracked in the system. In our case study, previous PLM launch, marketing specifications were exchanged by mails with problems of modification tracking and possible use of different versions depending on actors involved in the process. With PLM, marketing specification is created from a template and shared directly in PLM, accessible for all actors involved in the project as soon as marketing leader has decided to share this object with other project team members.

Use of PLM forces actors to codify a part of objects shared in the development process. Thus, PLM push actors to codify some objects which were mainly tacit or only partially codified before PLM. This codification enables to facilitate information sharing with more actors than if the object is tacit and restricted to some specialists which share common knowledge repository. This codification is complex for some objects and only a part of knowledge sharing can be codified and mediated by PLM solution. Thus, PLM supports closed commissioning objects which are already almost standardized and mature ones. The product technical sheet is a good example of standardisation of a commissioning object which is key for several actors of the development process. Product technical sheet defines all characteristics of a finish product with information such as color, overpackaging, gift box, rating plate. in PLM, all components of the finished products (rating plates, BOM, styling specifications) are managed as objects. Mechanism of technical sheet automatic generation in PLM is based on the consolidation of components of the finished product in a pdf predefined template. This automatic technical sheet enables to earn productivity in the compilation of components coming from different departments.

In PLM, this technical sheet is managed with revisions and status. This enables to follow modifications in every variant of finished products and be able to know which revision is the latest one and which one is validated. The implementation of this functionality has a positive impact in the quality of object shared in the design process and so it has improved reliability in technical sheet sharing on design process. Thus, errors in technical requirements on finished products have decreased since the implementation of PLM application. It is hard to give a precise quantitative reduction of errors but actors declare that errors due to bad revisions of technical sheets decrease twice with PLM.

Project structure and standardization of some objects facilitates integration of new actors in the process thanks to codified rules on the development process. This helps supplier integration in the development process and limit risks of misunderstandings between multiple actors which use their own rules with their own predefined mental structure.

Structuring of key milestones of the project relying on some standardized objects enables to facilitate department boundary exchanges for mature information. Thus, PLM facilitates integration of design with manufacturing thanks to standardized interfaces between applications and the standardisation of BOM and codification of components (bill of material and manufacturing range) on the whole product lifecycle management process. PLM also facilitates integration with CAD. For example, project leader can directly view the 2D and 3D drawings in PLM without the need of a designer.

PLM improves project monitoring

Thanks to some functionalities such as automatic generation of dashboards, PLM facilitates project monitoring. Project monitoring is facilitated by centralisation of all codified objects in a single database. Before PLM implementation, IO were split in several IT tools. Yet, one of the problems of project leader is the ability to monitor the evolution of project, task advancement on a daily basis. If preliminary, draft objects are partially shared in PLM, mature objects are available in PLM and so it is possible for project leader to follow his projects. He can have an overview of realisation of planning depending on the delivery of some objects which correspond to some tasks in development process. Thus, project leader can have directly state of advancement for lab tests, for industrialisation problems reporting, for styling and marketing sample needs etc…

PLM enables automatic generation of dashboards for two kinds of actors: operational actors and management. Concerning operational project dashboards, project leader and actors need to have a daily vision of project evolution in order to decide and manage risks on the project. Those dashboards combine different types of information: economic, planning and objects necessary for phase review. Project leaders underline that project monitoring functionalities to earn approximately half a day per week which was lost in information consolidation and validation before PLM launch. If value added for project monitoring is corroborated, *TeamCenter* solution implemented in our case didn't included the reporting module so existing dashboards were fixed and it was impossible to create new ones easily. Dashboard for laboratory department enables to better anticipate workload on each laboratory technician. Concerning management dashboards, they are primarly done for key performance indicators on the lead-time of project, respect of due dates and also analysis of the project and product portfolio. Those dashboards increase pressure on teams to reach objectives in term of schedule respect for example. For allocation of resources on projects, the work was done outside PLM.

Product monitoring is performed through product range dashboards. Those dashboards consolidate data from PLM in order to make analysis by product family, by project leader, by business unit.

PLM workflows tend to structure the exchange of information

In PLM, a part of project coordination is managed through workflows. Those workflows enable to validate and/or to diffuse objects during the development process. In *TeamCenter*, workflows are not ergonomic and relatively difficult to use. So it limits workflow use to simple workflows such as self validation or validation integrating a limited number of actors. Workflow management is not sufficiently flexible for real value added for users. Let's take the example of homologation workflow. This validation workflow includes multiple actors from different departments: technical, quality, standards department. On each step of the homologation process, actors need to validate or reject homologation request and if so add comments to justify his position. PLM workflows are technically too rigid to enable real interactions on validation process if complementary information are needed. So, in the case of PLM homologation workflow, actors interact by direct exchanges, phone or mail and when a compromise is found, they formally perform validation task in PLM workflow. So, PLM workflow just consists of a formal validation for tracking but has a limited value added to help, enrich and reduce time consumption on the validation process for a product homologation.

PLM can hardly be considered as real collaborative IT tool

Preliminary negotiations and constructions are performed outside PLM

Our analysis shows that PLM system does not really manage preliminary information exchanged by the actors. Despite the facilities to share information, we observe that there are few iterations on the preliminary draft objects through PLM. Thus, 75% of objects collected in PLM application have directly a validated or validation in progress status which means that preliminary exchanges between actors are done outside PLM application. Object collection in PLM is often done very close to the design review. Iterations on objects is managed through revision functionality. The day to day collaboration is performed by other ways. Thus, the level of e-mails with attached files is a clue to identify how those interactions, mutual adjustments between actors are performed.

If we observe the management of e-mail we can see that they explain elements for the use of the data that are sent. They can be considered as annotation and give indication to the maturity of the information produced. “please give advice of the part X but don’t take care of part y we are still working on” this exchange allow both to qualify the information sent and to help the team to plan their work and avoid reworks and iteration. Our interviews show that 75% of preliminary exchanges on collaborative engineering is performed through e-mails or direct interactions.

The use of e-mail is intuitive and enables to limit the scope of object sharing which is more difficult with PLM. E mails exchanges can be tracked. The e-mail response functionality allows to attach automatically the succession of exchanged. We often observe in design teams 5 or 6 pages e-mail that supported a specific problem resolution. People in design meeting arrive with a paper copy of the e-mail that support the discussion as well as the CAD datas.

In the case of large files that are not supported by e-mail, people often open specific areas like FTP or other shared repositories which are quite often not managed under PLM. This seems surprising whereas those actors could use the PLM facilities. One of the explanations is that they want to be sure that their drafts or exhibit won’t be used as validated data by other actors of the design. Most PLM organisations have defined conventional status of information that can be easily identified by users (for example green flag means ready to produce). But despite these possibilities, they don’t always use PLM to exchange information. Another hypothesis is that the preliminary information is shared in specific ad hoc groups that are defined by the producer for a specific purpose, while groups in the PLM are defined by the organisation. This point is more accurate in the large teams, when people don’t know each other. In Small teams when the confidence is good between actors we can observe that formal exchange spaces in PLM becomes open exchange or even private workspaces are open to other in reading mode. These examples show the necessity for PLM systems to integrate social dimension of collaborative design that they still partially do.

Workflows are too rigid for real collaborative engineering

The basic hypothesis of workflow is that the process can be divided in specific task that one actor can be responsible of. In the case of qualification of production workflow in the company we observed the difficulty to implement such a workflow.

There were two types of process depending where the production was made. In the case of Chinese externalisation for manufacturing, the workflow functionality of PLM was usable because the exchange of data was only based on deliverables. The stakes concerning the lead time and the cost of any modification imply that the process be clear. The confidence between stakeholders was low and the formal process was follow very closely.

The organisation of the same process for the part that was produced in the same plant was completely different. We have to consider that the constraints of time to market make the formal validation of all parts impossible. Design teams are responsible to qualify about one thousand of part for a single product. In fact they could not formally qualify all parts before the official launch of the product. The process was a very closely cooperative process with the production team. Thus the responsibility of the qualification of parts was spread between the two teams (design and production). This division of work was negotiated depending of the risk identified on the component and the high level of knowledge of the teams and the confidence in between them. The responsibility was informally transmitted to the production team for most of classical parts that do not present any risks depending of the charge the design team have to face. This negotiated division of work redefines dynamically the workflow that therefore could not be automated. This example shows that PLM systems are hard to support co-operation. The workflows well support collaborative design that is based on rule based coordination where tasks are identified and predefined. In co-operation the division of the work and the process is a result of the design itself. Thus workflow technologies should be more flexible and dynamically reconfigurable.

CONCLUSIONS

PLM improves transparency in mature knowledge sharing in the new product development process. However, PLM is quite rigid in daily collaborative engineering. TeamCenter Engineering is considered by users as not sufficiently intuitive which leads to problems for solution appropriation.
PLM enables to manage public and project collaborative spaces and so mainly mature objects. Draft and rough copies are not really mediated by PLM application because it is difficult to restrict object sharing to a limited number of actors outside project scope and because this tool is not really intuitive. PLM forces structuring of project management but doesn’t facilitate mediation of preliminary objects within actors.

Information sharing concept	Level of mediation with PLM	Comments
IO		
Closed commissionning object	++	Closed commissionning objects are well supported by PLM. Those objects enable to reinforce stage gate approach in project and this type of object transmits strong regulation: Quality specifications on a range of product for example.
open commissionning object	+	Open commissionning objects are quite well supported by PLM. Objects which are exchanged like 2 or 3 D drawings are shared by all PLM users.
Closed mediating object	-	Closed mediating objects are partially supported by PLM. Some objects such as preliminary technical specifications based on marketing requirements.
Open mediating object	--	Open mediating objects are not really supported by PLM but managed by web conferencing, direct contacts between actors, mails.
Sharing worskpaces		
private	--	Almost no private or proximity objects are collected in PLM because PLM is not sufficiently ergonomic to support preliminary knowledge sharing
proximity	-	
project	+	PLM manages mature objects and especillay information sharing at the project and public level
public	++	

Figure 4: PLM contribution to information sharing

It is important to highlight that the publication of preliminary information within the design-teams involves social aspects that the information systems have to take into account. We argue that the collaborative support systems should support this evolution of the information within specific workspaces. The designer is committed by the information he/she delivers to other actors. He could not diffuse drafts within any design workspace. Actors take care of the preliminary information that they diffuse in the design-team. This caution sometimes delays the disposal of the information for the others. The information exists but is not accessible. We argue that it is possible to spread preliminary information earlier, if we allow the providers to characterise its maturity.

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